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Tam et al.

[11] **4,246,448**

[45] **Jan. 20, 1981**

[54] **ELECTROMECHANICAL TRANSDUCER**

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[73] Assignee: **Uniroyal Ltd.,** Guelph, Canada

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Related U.S. Application Data

[63] Continuation of Ser. No. 615,669, Sep. 22, 1975, abandoned.

[30] **Foreign Application Priority Data**

Jul. 8, 1975 [CA] Canada 231048

[51] **Int. Cl.**³ **H04R 19/00;** B61F 17/00

[52] **U.S. Cl.** .... **179/111 E;** 179/111 R; 307/400

[58] **Field of Search** .... 179/111 R, 111 E; 307/88 ET

[56] **References Cited**

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3,821,492	6/1974	Tamura et al.	179/111 E
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[57] **ABSTRACT**

An electromechanical electret transducer suitable for push-pull operation includes multiple vibratory diaphragms acoustically coupled to each other to increase the output sound pressure. Since the diaphragms physically shield the stationary electrets, the adverse environmental effects on the charge stabilities of the electrets are minimized.

7 Claims, 3 Drawing Figures

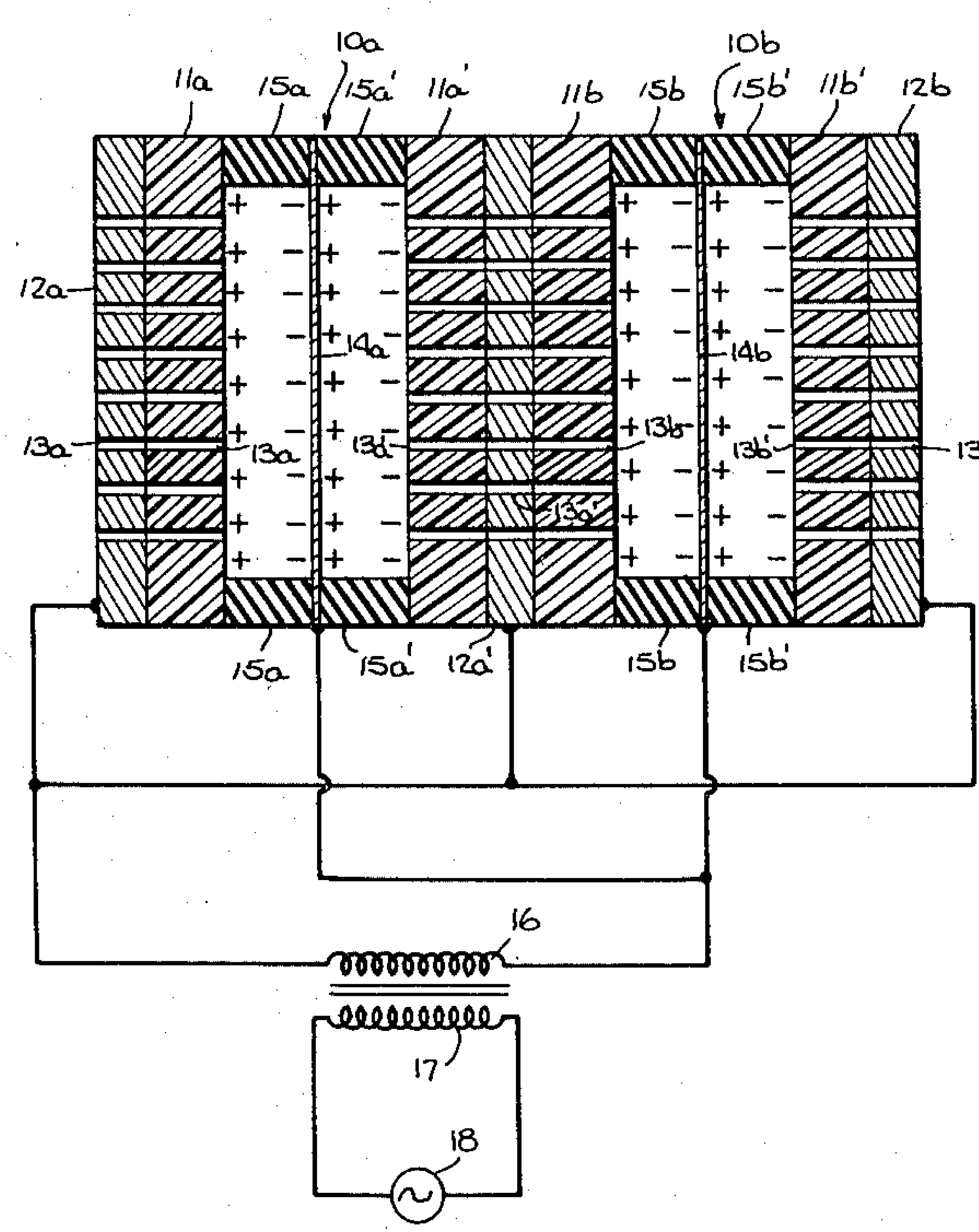

Fig. 1.

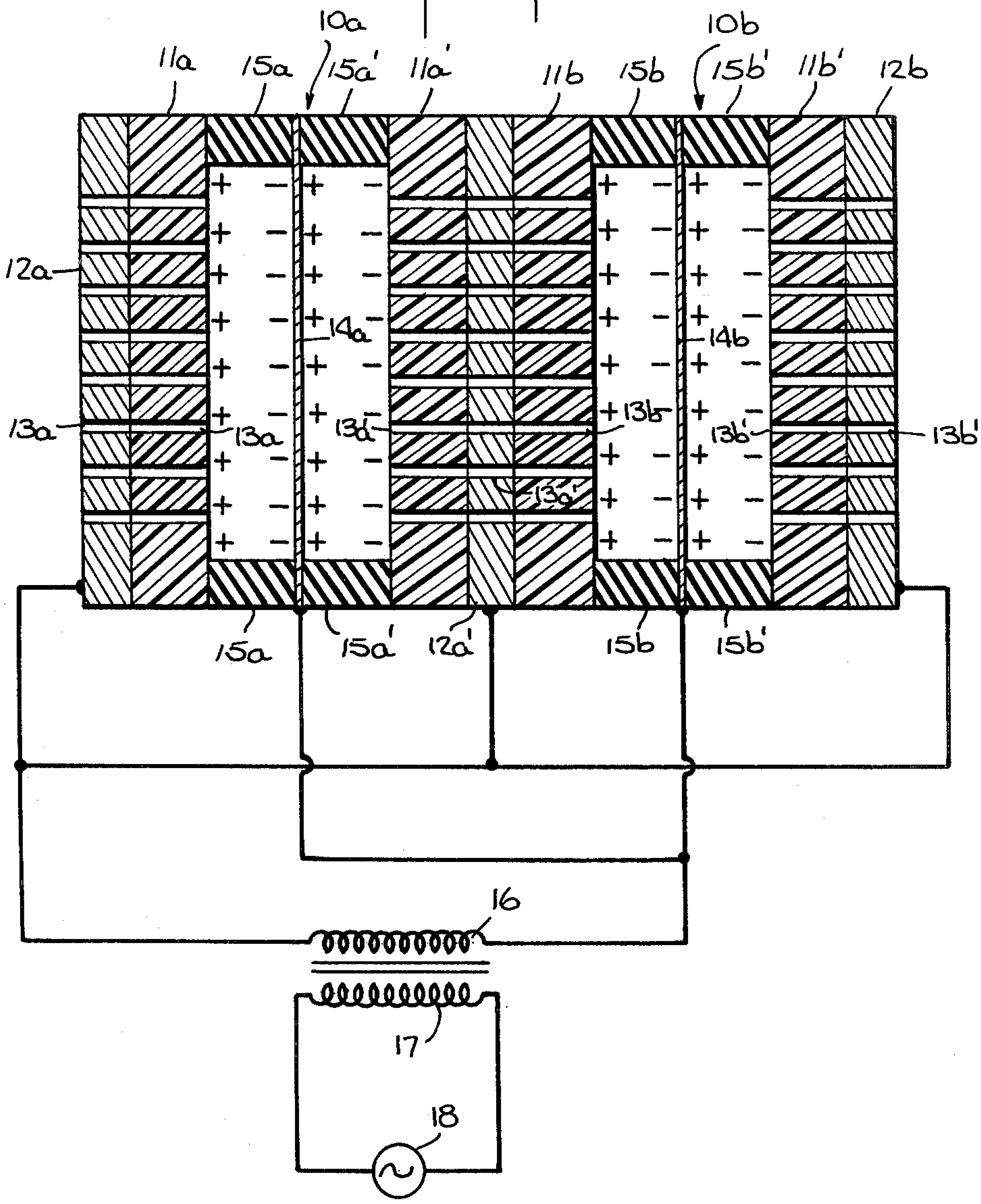
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Fig. 2.

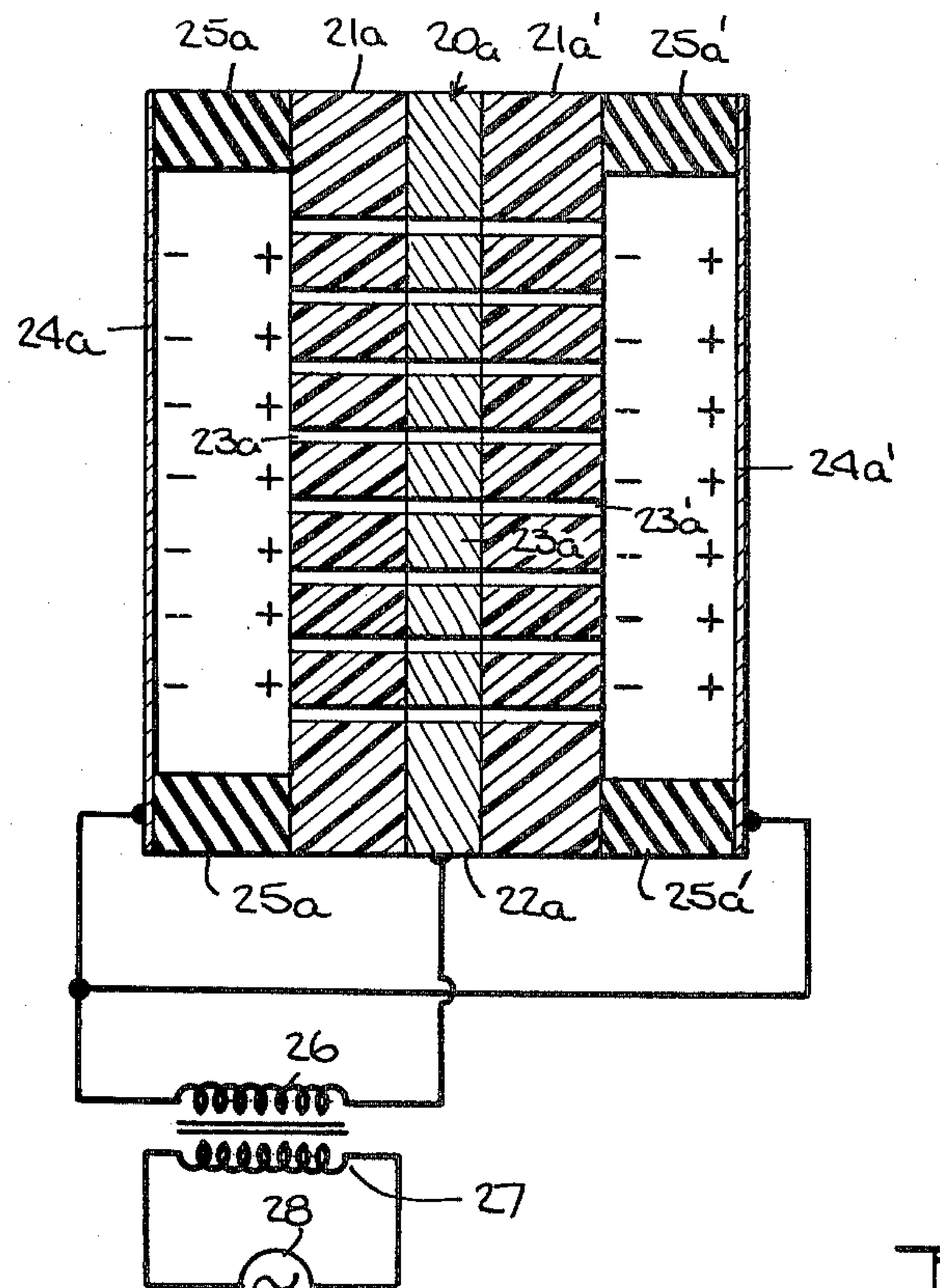
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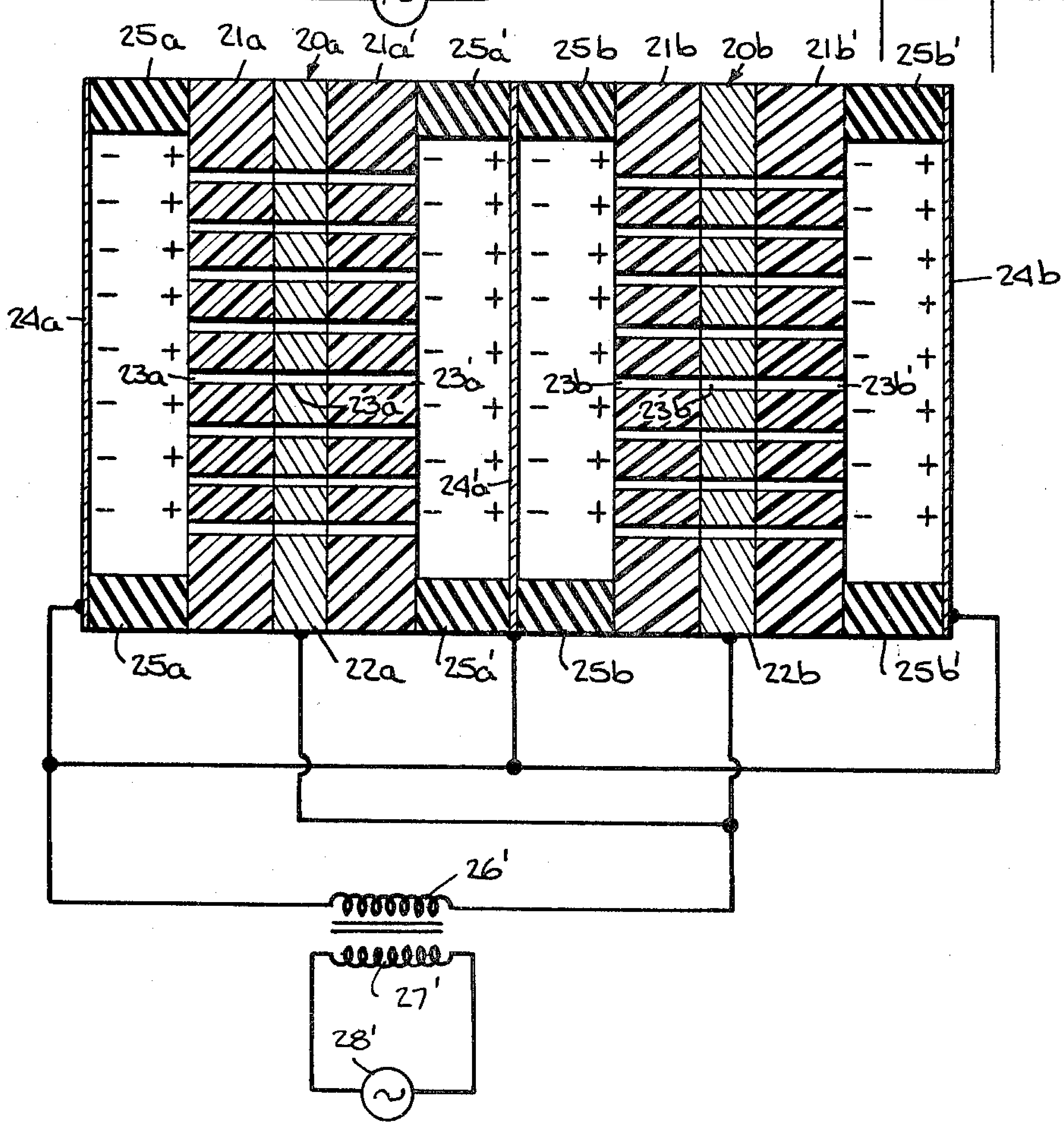
Fig. 3.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ELECTROMECHANICAL TRANSDUCER

This is a continuation of application Ser. No. 615,669, filed Sept. 22, 1975 now abandoned.

This invention relates to electromechanical transducers, and, more particularly, to electrostatic electroacoustic transducers of the type utilizing a plurality of stationary electrets in a construction suitable for push-pull operation without requiring an external direct-current bias voltage and including a plurality of vibratory diaphragms acoustically coupled to each other to increase the output sound pressure. Since these diaphragms also physically shield the electrets, the adverse environmental effects on the charge stabilities of the electrets are minimized.

A prior electrostatic transducer is described in U.S. Pat. No. 3,136,367-Brettell which requires an external active high direct-current bias voltage source and a center-tapped transformer. A plurality of vibratory diaphragms are mounted in a structure of stacked frames with perforated metal electrodes between the diaphragms. Direct-current bias voltage is applied to the diaphragms by connecting successive diaphragms to opposite terminals of a direct-current high voltage supply having a grounded center tap. The terminals of a center-tapped transformer are alternately connected to successive metal electrodes and the center tap is grounded. An improved sound power output is obtained as compared with a similar transducer having a single diaphragm, but the transducer has the disadvantage of requiring a high direct-current voltage supply and a center-tapped transformer, presenting a high voltage hazard, complicated design problems and additional cost.

An electrostatic headphone using a plurality of foil electrets as the vibratory diaphragms each, for example, 0.25 mil thick and held between two rigid perforated metal plates is described in U.S. Pat. No. 3,118,022-Sessler et al. Since foil electrets are capable of supplying only approximately 200 volts of equivalent direct-current bias voltage, this relatively low equivalent direct-current bias voltage imposes a severe limitation on the maximum input audio signal that can be applied, hence restricting sound output of the transducer. To avoid severe harmonic distortion, the maximum input audio signal voltage must at no time exceed the direct-current bias voltage. In the case of an electrostatic loudspeaker which requires an equivalent direct-current bias voltage of the order of kilovolts, foil electrets are totally inadequate. There is another great disadvantage in using the electrets as the vibratory diaphragms. In order to achieve a stable and specified performance of the transducer, it is necessary to control the diaphragm tension and to maintain a constant geometry. Since most known good polymeric electrets, for example, Teflon-FEP, have relatively poor mechanical properties and exhibit creep, i.e. continuous expansion under constant stress, it is thus extremely difficult to achieve constant diaphragm tension and stable performance using electrets as vibratory diaphragms.

A transducer of the prior art utilizing electrets is described in Canadian Pat. No. 908,281-Tamura et al. The transducer utilizes two rigid perforated metal electrodes, two perforated electrets, and a conductive thin vibratory diaphragm. The perforations on the metal electrodes and the electrets are substantially aligned to permit passage of acoustic radiation from the vibratory diaphragm which is positioned midway between the two electrets. The polarities of the electrical charges on the surfaces of the electrets facing the diaphragm are opposite in sign. The audio signal source is connected to the primary windings of the transformer. The two metal electrodes are connected to one terminal and the diaphragm to the other terminal of the secondary windings of the transformer. This transducer has the disadvantage of having only limited sound output capability, particularly in the low frequency range, because of the necessity of using a narrow spacing between the diaphragm and the electrets. Another disadvantage of this transducer is that the electrets are not protected from the adverse effects of outside environment such as humidity, ions and dust present in the atmosphere etc. It is well known that surface charges of even superior electrets, such as Teflon-FEP, decay more rapidly if exposed to humidity or ions present in the atmosphere. It is therefore difficult for the transducer to maintain a stable performance over long periods of time.

It is an object of the present invention, therefore, to provide a new and improved electromechanical transducer which avoids one or more disadvantages of such prior transducers.

It is another object of the invention to provide a new and improved transducer utilizing an electret construction and suitable for push-pull operation.

It is another object of the invention to provide a new and improved transducer utilizing an electret construction and suitable for push-pull operation and having improved sound power output capability.

It is another object of the invention to provide a new and improved transducer utilizing a simple electret construction and suitable for push-pull operation.

It is another object of the invention to provide a new and improved transducer utilizing an electret construction in which the electrets are stationary. This construction offers flexibility in selecting the appropriate materials to suit the requirement of mechanical properties of diaphragms and the requirement of electrical properties of electrets.

It is another object of the invention to provide a new and improved transducer utilizing an electret construction in which the electrets are physically shielded from the detrimental effects of outside environment on the surface charge stability of electrets. Thus the transducer can maintain stable performance over a long period of time.

It is another object of the invention to provide a new and improved transducer utilizing an electret construction in which the electrets are capable of supplying an equivalent direct-current bias voltage of several kilovolts. Thus higher input audio signal voltage can be applied to increase the output sound pressure without introducing objectionable harmonic distortion.

It is another object of the invention to provide a new and improved transducer utilizing an electret construction and suitable for push-pull operation as a loudspeaker or a headphone which achieve good fidelity. This transducer can also be used as a sound microphone or as an ultrasonic generator or receiver.

In accordance with the invention, an electromechanical transducer comprises a first pair of electrostatically polarized stator electrets, and conductive means adjacent each of the electrets, the electrets and the conductive means each having apertures therethrough. The transducer also includes first thin vibratory diaphragm means comprising a layer of conductive material, means for supporting the diaphragm means between the electrets in spaced relation thereto, the electrets being polarized to develop electrical charges of opposite polarity on the surfaces of the electrets facing the diaphragm means. The transducer also includes a second pair of electrostatically polarized stator electrets, one of the second pair of electrets being adjacent one of the first pair of conductive means. The transducer also includes third conductive means adjacent the other electret of the second pair. The second pair of electrets and the conductive means adjacent thereto each have apertures therethrough. The transducer also includes second thin vibratory diaphragm means comprising a layer of conductive material, and means for supporting the second diaphragm means between the second pair of electrets in spaced relation thereto. The second pair of electrets is polarized to develop electrical charges of opposite polarity on the surfaces of the second pair of electrets facing said second diaphragm means and the second pair of electrets also is polarized to develop electrical charges of the same polarity as corresponding electrets of the first pair develop on the surfaces thereof facing the first diaphragm means. The first and second diaphragm means are acoustically coupled.

Also in accordance with the invention, an electromechanical transducer comprises a pair of electrostatically polarized stator electrets, conductive means adjacent the electrets, the electrets and the conductive means each having apertures therethrough. The transducer also includes first and second thin vibratory diaphragm means each comprising a layer of conductive material, means for supporting the first diaphragm means in spaced relation to one of the electrets, and means for supporting the second diaphragm means in spaced relation to the other electret. The electrets and the conductive means are disposed between the first and second diaphragm means. The electrets are polarized to develop electrical charges of opposite polarity on the surface of the electrets facing the diaphragm means. The diaphragm means are acoustically coupled.

By stator electrets is meant electrets which are stationary within the transducer insofar as mechanical vibrations, for example, sound-reproducing vibrations are concerned.

As used herein, the term acoustically coupled is not limited to mean coupling at frequencies within the audible range but may refer to coupling at frequencies above the audible range for ultrasonic transducers.

For a better understanding of the present invention, together with other and further objects thereof, reference is made to the following description, taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

Referring now to the drawings:

FIG. 1 is a schematic sectional view of a transducer constructed in accordance with the invention;

FIG. 2 is a schematic sectional view of another embodiment of a transducer constructed in accordance with the invention, and

FIG. 3 is a schematic sectional view of another embodiment of a transducer constructed in accordance with the invention.

For a better understanding of the present invention, together with other and further objects thereof, reference is made to the following description, taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

Referring now more particularly to FIG. 1 of the drawings, an electromechanical transducer in accordance with the invention preferably includes a plurality, for example, two, substantially identical sounding units **10a** and **10b** but having one electrode in common. The sounding unit **10a** comprises a first pair of electrostatically polarized electrets **11a,11a'**. The electrets **11a,11a'** are sheet electrets each having a thickness preferably in the range of 5 mils to 100 mils, for example, 20 mils. The electrets **11a,11a'** may be any dielectric material which is capable of storing electrical charges for a long period of time, for example, polychlorotrifluoroethylene available under the trademark Aclar of Allied Chemical Corporation or tetrafluoroethylene-hexafluoropropylene copolymer available under the trademark Teflon-FEP of E. I. du Pont de Nemours & Co. The surface charge density of each electret may be, for example, 5×10^{-8} coulombs per square centimeter. The electrets may be charged by any known techniques such as corona discharge or scanning electron beam.

Each electret **11a,11a'** has conductive means **12a,12a'** adjacent thereto. The conductive means **12a,12a'** preferably are rigid metal electrodes and may be, for example, aluminum plates of 20 mils thickness. The thickness of the electrodes is not critical. The electrets **11a,11a'** and the conductive means **12a,12a'** each have apertures **13a,13a'** therethrough which may be provided by perforating the electrets and the adjacent electrodes in a desired pattern with the apertures of each electret and its adjacent electrode being substantially aligned. Each of the apertures preferably has a diameter in the range of 1/16 to ¼ inch, for example, 3/32 inch. The apertures preferably are uniformly distributed and the total area of the apertures may be 33 percent of the total area of each electret, as may be determined by the maximum sound transmission efficiency.

The sounding unit **10a** also includes first thin vibratory diaphragm means **14a** comprising a layer of conductive material. The diaphragm means preferably comprises a polyethylene terephthalate film, available under the trademark Mylar of E. I. du Pont de Nemours & Co., metallized on at least one side. The Mylar material of the diaphragm means preferably has a thickness in the range of ¼ to 2 mil and may be, for example, ½ mil thick.

The sounding unit **10a** also includes means for supporting the diaphragm means **14a** between the electrets **11a,11a'** in spaced relation thereto throughout the dynamic operation of the diaphragm means **14a** comprising, for example, suitable frames **15a,15a'**, for example, cardboard frames which are adhesively bonded to the diaphragm means **14a** held in stretched condition thereon. Suitable electrical connections are provided for the diaphragm means **14a**. The cardboard frames preferably have a thickness in the range of 0.005 inch to 0.25 inch and thus provide an air gap distance of a 0.005 inch to 0.25 inch between the diaphragm means and each electret **11a,11a'**.

The electrets **11a,11a'** are polarized to develop electrical charges of opposite polarity on the surfaces of the electrets facing the diaphragm means **14a**, as represented schematically in FIG. 1.

The sounding unit **10b** of the transducer includes a second pair of electrostatically polarized electrets **11b,11b'** preferably having conductive means **12a',12b** adjacent thereto. One of the second pair of electrets **11b** is adjacent the conductive means **12a'** between electrets **11a',11b**.

The second pair of electrets **11**b,**11**b' and the conductive means **12**a',**12**b adjacent thereto have apertures **13**b,**13**b' therethrough as represented in FIG. **1**. The apertures **13**b of the electret **11**b adjacent the conductive means **12**a' are preferably substantially aligned with the apertures **13**a' of the adjacent electret **11**a' and conductive means **12**a'.

The second sounding unit **10**b includes second thin vibratory diaphragm means **14**b comprising a layer of conductive material and being similar to diaphragm means **14**a. The second sounding unit **10**b also includes means **15**b,**15**b' for supporting the second diaphragm means **14**b between the second pair of electrets **11**b,**11**b' in spaced relation thereto throughout the dynamic operation of the second diaphragm means **14**b. The second pair of electrets **11**b,**11**b' is polarized to develop electrical charges of opposite polarity on the surfaces of the second pair of electrets facing the diaphragm means **14**b, as represented diagrammatically in FIG. **1**. The second pair of electrets **11**b,**11**b' also is polarized to develop electrical charges of the same polarity as corresponding electrets **11**a,**11**a' of the first pair develop on the sufaces thereof facing the first diaphragm means **14**a.

The first and second diaphragm means **14**a,**14**b are so acoustically coupled to each other through the aligned apertures **13**a',**13**b as to vibrate in unison throughout the dynamic operation of the transducer.

The perforated metal electrodes **12**a,**12**a', **12**b, the electrets **11**a,**11**a', **11**b,**11**b', the diaphragm means **14**a,**14**b, and the diaphragm-supporting means **15**a,**15**a', **15**b,**15**b' are assembled into the configuration shown schematically in FIG. **1**. The whole assembly can be, for example, secured by plastic screws and supported in suitable housing units (not shown).

There is coupled to the FIG. **1** transducer circuit means for applying an alternating-current signal between the diaphragm means **14**a,**14**b and the conductive means **12**a,**12**a', **12**b. The diaphragm means **14**a,**14**b are electrically connected and the conductive means **12**a,**12**a', **12**b are electrically connected. The circuit means comprises, for example, the secondary winding **16** of a step-up transformer having one terminal connected to diaphragm means **14**a,**14**b and the other terminal connected to the conductive means **12**a,**12**a', **12**b. The primary winding **17** of the transformer is connected to, for example, a suitable audio-frequency signal source **18**.

Considering now the operation of the FIG. **1** transducer and referring first to the single sounding unit **10**a, when there is no audio signal applied, the diaphragm **14**a will be subject to equal attractive electrostatic forces on each side and will thus remain in equilibrium at the mid-position. However, when an alternating audio signal is applied, the two metal electrodes **12**a,**12**a' are simultaneously charged with the same amount of electrical charge resulting in an increase of the surface charge of one electret, for example, electret **11**a and a decrease of the surface charge of the other electret, for example, electret **11**a'. The diaphragm is thus forced to move towards one side. As the audio-signal polarity reverses, the diaphragm is forced to move to the other side. It is well known that such a push-pull operation inherently reduces harmonic distortion to the lowest possible levels.

Considering now the operation of both sounding units **10**a,**10**b, the diaphragms **14**a,**14**b move in the same direction in response to an applied audio signal and move in the opposite direction as the polarity of the audio signal reverses. However, since the trapped air between diaphragms behaves as a stiff medium acoustically, the sounding units **10**a, **10**b are thus acoustically coupled to each other. Either of the diaphragms **14**a,**14**b, apart from being acted upon by electrostatic forces, is also subjected to acoustic forces which are generated by the vibratory motion of the other diaphragm. Since these forces are additive, the output sound pressure from the transducer is increased. It is clear, therefore, that additional sounding units similar to the sounding units **10**a,**10**b may be stacked with the units **10**a,**10**b and acoustically coupled thereto and electrically connected in a manner similar to units **10**a,**10**b.

Referring now to FIG. **2** of the drawings, a transducer preferably comprises a sounding unit **20**a including a pair of electrostatically polarized stator electrets **21**a,**21**a'. The electrets **21**a,**21**a' and the conductive means **22**a each have apertures **23**a,**23**a' therethrough. The apertures **23**a,**23**a' of the electrets **21**a,**21**a' and the conductive means **22**a preferably are substantially aligned. The transducer also includes thin vibratory diaphragm means **24**a,**24**a' each comprising a thin layer of conductive material, means **25**a for supporting the first diaphragm means **24**a in spaced relation to one of the electrets **21**a throughout the dynamic operation of the first diaphragm means **24**a, and means **25**a' for supporting the second diaphragm means **24**a' in spaced relation to the other electret **21**a' throughout the dynamic operation of the second diaphragm means **24**a'. The electrets **21**a,**21**a' and the conductive means **22**a are disposed between the first and second diaphragm means **24**a,**24**a'. The electrets **21**a,**21**a' are polarized to develop electrical charges of opposite polarity on the surfaces of the electrets facing the diaphragm means **24**a,**24**a', as represented schematically in FIG. **2**. The first and second diaphragm means **24**a,**24**a' are acoustically coupled.

The electrets **21**a,**21**a', conductive means **22**a, diaphragm means **24**a,**24**a' and diaphragm supporting means **25**a,**25**a' may be of similar construction to the corresponding members of the FIG. **1** transducer and accordingly will not be described in detail.

The diaphragm means **24**a,**24**a' are electrically connected, for example, to one terminal of the secondary winding **26** of a step-up transformer and the conductive means **22**a is electrically connected, for example, to the other terminal of the secondary winding **26**. For example, an audio-signal source **28** is connected to the primary winding **27** of the transformer.

Considering now the operation of the sounding unit **20** represented in FIG. **2**, since the polarities of the electrical charges on the surfaces of the electrets **21**a,**21**a' facing the diaphragms **24**a,**24**a' are opposite in sign, the induced surface charges on the two diaphragms are also of opposite polarites. When there is no audio signal applied, each diaphragm **24**a,**24**a' is attracted toward the electrets **21**a,**21**a' to achieve a static equilibrium position. However, when an audio signal is applied, the two diaphragms are simultaneously charged with the same amount of electrical charge, resulting in an increase of surface charge of one electret, for example, electret **21**a and a decrease of surface charge of the other electret, for example, electret **21**a'. Both diaphragms and thus forced to move towards one side. This can also be considered as a push-pull operation in the sense that one diaphragm is pushed by one electret and the other diaphragm is pulled by the other electret. As the audio signal polarity reverses, both diaphragms are forced to move to the other side. Also, the air trapped between the diaphragms acts as a stiff acoustic medium, and each diaphragm, apart from being acted upon by electrostatic force, is also subject to acoustic forces generated by the vibratory motion of the other diaphragm. These forces are additive and thus the diaphragms are so acoustically coupled as to vibrate in unison throughout the dynamic operation of the transducer.

Referring now to FIG. 3, the transducer there represented preferably includes a sounding unit **20***a* substantially identical with the FIG. 2 sounding unit **20***a* and also preferably includes a second sounding unit **20***b* substantially identical with the sounding unit **20***a* but having a diaphragm means **24***a'* in common therewith. The sounding unit **20***b* includes a second pair of electrostatically polarized stator electrets **21***b*,**21***b'* and conductive means **22***b* adjacent the second pair of electrets **21***b*,**21***b'*. The second pair of electrets **21***b*,**21***b'* and the conductive means **22***b* have apertures **23***b*,**23***b'* therethrough. The sounding unit **20***b* includes means **25***b* for supporting the second diaphragm means **24***a'* in spaced relation to electret **21***b* of the second pair of electrets **21***b*,**21***b'* throughout the dynamic operation of the second diaphragm means **24***a'*. The sounding unit **20***b* also includes third thin vibratory diaphragm means **24***b* comprising a layer of conductive material and means **25***b'* for supporting the third diaphragm means **24***b* in spaced relation to electret **21***b'* of the second pair of electrets **21***b*,**21***b'* throughout the dynamic operation of the third diaphragm means **24***b*.

The second pair of electrets **21***b*,**21***b'* and the conductive means **22***b* adjacent thereto are disposed between the second diaphragm means **24***a'* and the third diaphragm means **24***b*. The second pair of electrets **21***b*,**21***b'* is polarized to develop electrical charges of opposite polarity on the surfaces of the second pair of electrets **21***b*,**21***b'* facing the second and third diaphragm means **24***a'*,**24***b*, as represented schematically in FIG. 3. The second pair of electrets **21***b*,**21***b'* facing the second and third diaphragm means **24***a'*, **24***b* also is polarized to develop electrical charges of the same polarity as corresponding electrets **21***a*,**21***a'* of the first pair develop on the surfaces thereof facing the first and second diaphragm means **24***a*,**24***a'* respectively. The first, second and third diaphragm means **24***a*,**24***a'*,**24***b* are so acoustically coupled through the apertures **23***a*,**23***a'*,**23***b*,**23***b'* as to vibrate in unison throughout the dynamic operation of the transducer.

Circuit means comprising, for example, the secondary winding **26'** of a step-up transformer is electrically connected to the sounding units **20***a*, **20***b* for applying an alternating current signal between the diaphragm means **24***a*,**24***a'*,**24***b* and the conductive means **22***a*, **22***b*. The diaphragm means **24***a*,**24***a'*, **24***b* are electrically connected and the conductive means **22***a*, **22***b* are electrically connected. For example, an audio-signal source **28'** is connected to the primary winding **27'** of the transformer.

Considering now the operation of the FIG. 3 transducer, the sounding unit **20***a* of FIG. 3 operates in the same manner as the sounding unit **20***a* of FIG. 2. The sounding unit **20***b* also operates in the same manner as the sounding unit **20***a* of FIG. 2. However, with the sounding units **20***a*, **20***b* acoustically coupled together and with the trapped air acting as a stiff acoustic medium, any one of the diaphragms **24***a*,**24***a'*,**24***b*, apart from being acted upon by electrostatic forces, is also subject to acoustic forces which are generated by the vibratory motion of the other diaphragms. Since these forces are additive, the output sound pressure from the transducer is increased. It is clear, therefore, that additional sounding units similar to the sounding units **20***a*,**20***b* may be stacked with the units **20***a*, **20***b* and acoustically coupled thereto and electrically connected in a manner similar to units **20***a*,**20***b*.

Transducers constructed in accordance with the present invention have many advantages over prior art. For the same diaphragm (sound-radiating) area and applied audio signal voltage, the output sound pressure is many times larger than that of electrostatic transducers based on the prior art. This permits a considerable reduction of diaphragm area to achieve the same amount of sound output as prior electrostatic transducers.

Also, by using sheet electrets having a minimum thickness of 5 mils instead of foil electrets, higher equivalent direct-current bias voltage can be obtained. Thus, high audio-signal voltage can be used without producing objectionable harmonic distortion. Also, since the electrets are stationary, it is thus possible to use different materials to satisfy the requirements of the mechanical properties of the vibratory diaphragms and the requirements of the electrical properties of the electrets.

Further, since a center-tapped transformer is not required, the transformer may be smaller in size, lighter in weight and less expensive to produce.

Additionally, because an active high direct-current voltage supply is not used, high voltage shock hazard, complications in design, and higher cost associated with the high voltage supply and insulation are eliminated.

Also, unlike conventional electrostatic electroacoustic transducers in which the audio-signal voltage is divided between the electrodes, the signal voltage in the transducers according to the present invention is applied between the electrodes and the diaphragms. Therefore, voltage sensitivity is doubled. In otherwords, only half the signal voltage is required to produce the same amount of output sound pressure.

Further, since the electrets are either totally physically shielded (as in the FIGS. 2 and 3 transducers) or partially physically shielded (as in the FIG. 1 transducer) by the vibratory diaphragms from outside environment (humidity, dust, ions, etc.), the decay of surface charge of electrets usually associated with humidity or ions present in the atmosphere is thus eliminated or minimized. It is well known that the surface charges of electrets decay more rapidly when the electrets are exposed to humidity or to ions present in the atmosphere.

Using 20 mil Teflon-FEP electrets, 0.25 mil Mylar film as vibratory diaphragms, and 20 mil cardboard frames as spacers between electrets and vibratory diaphragms, electret headphones in accordance with the FIG. 1 and FIG. 3 embodiments have a flat frequency response (within ± 3 decibels) from 20 Hertz to 20 Kilohertz. With 100 alternating-current volts as input signal into the headphones, the output sound pressure level was about 105 decibels. At 90 decibels or lower output sound pressure level, total harmonic distortion was less than one percent over the entire audio frequency band from 30 Hertz to 20 Kilohertz. The transducer also had good square wave response at, for example, 200 Hertz and 95 decibels output sound pressure level, indicating it is capable of superior transient response.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed to cover all such changes and modifications as fall within the true spirit and scope of the invention.

We claim:

1. An electromechanical push-pull transducer comprising a first pair of electrostatically polarized stator electrets, conductive means adjacent each of said electrets, said electrets and said conductive means each having apertures therethrough, a first thin vibratory internally non-polarized diaphragm comprising a layer of conductive material, means for supporting said diaphragm between said electrets in spaced relation thereto throughout the dynamic operation of said diaphragm, said electrets being polarized to develop electrical charges of opposite polarity on the surfaces of said electrets facing said diaphragm, a second pair of electrostatically polarized stator electrets, one of said second pair of electrets being adjacent one of said conductive means, conductive means adjacent the other electret of said second pair, said second pair of electrets and said conductive means adjacent thereto each having apertures therethrough, a second thin vibratory internally non-polarized diaphragm comprising a layer of conductive material, means for supporting said second diaphragm between said second pair of electrets in spaced relation thereto throughout the dynamic operation of said second diaphragm, said second pair of electrets being polarized to develop electrical charges of opposite polarity on the surfaces of said second pair of electrets facing said second diaphragm, said second pair of electrets also being polarized to develop electrical charges of the same polarity as corresponding electrets of said first pair develop on said surfaces thereof facing said first diaphragm, said first and second diaphragms being so acoustically coupled as to vibrate in unison throughout the dynamic operation of the transducer, and circuit means for applying an alternating current signal between said diaphragms and said conductive means, said diaphragms being electrically connected and said conductive means being electrically connected.

2. A transducer in accordance with claim 1 in which said apertures of said electrets and said conductive means adjacent thereto are substantially aligned.

3. A transducer in accordance with claim 1 suitable for use as a headphone and in which each diaphragm covers uniformly substantially the entire audio frequency range.

4. An electromechanical push-pull transducer comprising a pair of electrostatically polarized stator electrets, conductive means adjacent said electrets, said electrets and said conductive means each having apertures therethrough, first and second thin vibratory internally non-polarized diaphragms each comprising a layer of conductive material, means for supporting said first diaphragm in spaced relation to one of said electrets throughout the dynamic operation of said first diaphragm, said first diaphragm being an external electrostatic member of said transducer, and means for supporting said second diaphragm in spaced relation to the other of said electrets throughout the dynamic operation of said second diaphragm, said electrets and said conductive means being disposed between said first and second diaphragms, said electrets being polarized to develop electrical charges of opposite polarity on the surfaces of said electrets facing said diaphragms, said first and second diaphragms being so acoustically coupled as to vibrate in unison throughout the dynamic operation of the transducer, a second pair of electrostatically polarized stator electrets, conductive means adjacent said second pair of electrets, said second pair of electrets and said conductive means adjacent thereto each having apertures therethrough, means for supporting said second diaphragm in spaced relation to one of said second pair of electrets throughout the dynamic operation of said second diaphragm, a third thin vibratory internally non-polarized diaphragm comprising a layer of conductive material, and means for supporting said third diaphragm in spaced relation to the other of said second pair of electrets throughout the dynamic operation of said third diaphragm, said second pair of electrets and said conductive means adjacent thereto being disposed between said second and third diaphragms, said second pair of electrets being polarized to develop electrical charges of opposite polarity on the surfaces of said second pair of electrets facing said second and third diaphragms, said second pair of electrets facing said second and third diaphragms also being polarized to develop electrical charges of the same polarity as corresponding electrets of said first pair develop on said surfaces thereof facing said first and second diaphragms, respectively, said first, second and third diaphragms being so acoustically coupled as to vibrate in unison throughout the dynamic operation of the transducer.

5. A transducer in accordance with claim 3 suitable for use as a heaphone and in which each diaphragm covers uniformly substantially the entire audio frequency range.

6. A transducer in accordance with claim 3 in which said third diaphragm is an external electrostatic member of said transducer.

7. A transducer in accordance with claim 4 and circuit means coupled thereto for applying an alternating current signal between said diaphragms and said conductive means, said diaphragms being electrically connected and said conductive means being electrically connected.

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